that only once, 1921, has a large yield followed such a set of circumstances, so deterioration may be expected to set in soon." Following that date, the Bureau of Agricultural Economics of the United States Department of Agriculture showed a reduction of more than 100,000,000 bushels in the estimate of the Iowa corn crop. Such a thing is of vast agricultural and commercial importance. Thus at the close of an abnormally cold January, it would be the best sort of business sense to keep train loads of fuel moving into Iowa. Again a mild January indicates a large number of eggs going to market from Iowa in February and a cold January the reverse.

ON THE OCCASIONS, OR INCIDENTAL CAUSES, OF EXTRATROPICAL CYCLONES

By W. J. HUMPHREYS

Because the earth is continuously warmest within the Tropics and coldest in the polar regions there must be a corresponding amount of ceaseless interzonal circulation of the atmosphere. And because the earth is rotating, this circulation must largely occur in "fits and starts" and cross the middle latitudes in the great swirls and eddies that we call cyclones and anticyclones—must, as has been proved [1] mathematically, and as is evident from the fact that that is the way it does occur.

Cyclones are inevitable. They must occur somewhere, and frequently, for the reasons stated, but exactly when and where they shall start are occasioned or determined by entirely secondary causes. It is these initiating or incidental causes alone that are here considered.

Fundamentally an extratropical cyclone is an extensive eddy or swirl between two winds of different origin, direction, and temperature. Such winds are always blowing. They are the mutually compensating branches of the continuous, interzonal circulation between the warmer and colder portions of the earth. But how are they brought each so decidedly under the influence of the other that an eddy is established between them?

This is effected:

1. By the interplay between oppositely directed warm and cold currents of air adjacent to each other.
2. By a more or less circular, cyclonic rotation, however established, of the air over an extratropical area of suitable size, a process that draws to the western side colder air from higher latitudes and to the eastern side warmer air from lower latitudes.

Considering the first of these methods in greater detail: Owing to the continuous circulation of the atmosphere between the tropical and polar regions warm and cold currents frequently flow side by side in opposite directions, and because of the rotation of the earth the interface between them necessarily is to the left of one going with either current, in the Northern Hemisphere; to his right in the Southern Hemisphere. In this case the two currents of air, though of unequal densities, level for level, may be in equilibrium with each other, the colder wedged at a small angle under the warmer, and flow on without mutual interference—but not for long; the balance is too delicate for that. And wherever the break-down occurs it simultaneously affects both currents. The colder air invades the territory of the warmer while the warmer, on the eastern side of the break, swings into the region of the colder, and, of course, up the interface as up the side of a gently rising mountain. This juxtaposition of distinct air currents occasions most of the extratropical cyclones, and is effective wherever such storms occur. This action is well illustrated by charts A and B.

The second of the two general methods of starting the extratropical cyclone, listed above, may be variously subdivided. One such division is:

a. The invasion of extratropical regions by a cyclone of tropical origin. In this case a continuous storm path may be traced, but not a track of a continuous storm, in the sense of one having all the time the same characteristics. Once it was a mighty whirl in a mass of air of common origin and of substantially the same temperature and humidity on every side, but later, at higher latitudes, and where the conditions already were favorable, it gradually *occasioned* (did not develop or transform into) an extratropical cyclone, or swirl between polar and tropical winds. An excellent example of this sequence of events followed the famous Galveston hurricane of September 9, 1900, as shown on plate C.

b. Persistent relatively high temperature over an area of considerable extent. This causes a greater or less convection over the area in question with a cyclonic circulation round about. In high latitudes, where the influence of the rotation of the earth is strong, this circulation in turn often develops a secondary cyclone in the eastern side of the warmer area. This secondary then moves off as a traveling, independent cyclone and later often assumes large proportions. An example of this genasis of a cyclone is shown on charts D and E.

It must be noted, however, that the particular region shown on these charts, namely, the Gulf of Alaska, is, during the winter, one into which many cyclones come from the west, as well as one from which many emerge to the east. Is it then just a portion of a channel along which the storms pass, as many in as out and substantially unchanged, or is it ever a cyclonic reservoir, as it were, with an outflow more or less independent of the obvious inflow? It is certain that more cyclones leave this region than would if none entered it, and we infer that, owing to its relatively high temperature, the storms leaving it are greater in number than those entering, and commonly different in size and intensity as well—inferences that appear to be abundantly supported by observation. In short, we infer and believe that some of the storms that leave this region had also their origin there, or were occasioned by it.

c. Relatively high temperatures, due to insolation, over land. The cyclones thus induced, "heat" LOWS, they have been called, commonly are feeble and of little importance. A cyclone that appears to have been contributed to in this way, starting as a California valley LOW, is shown on charts F to H, inclusive.

d. The heating of the air over a considerable area by foehn or chinook winds. Charts I to L, inclusive, show a good example of a cyclone initiated in this interesting way.

There is nothing really new in this paper, nevertheless the emphasis on the several examples afforded by the charts may be helpful to at least some students of this daily puzzle, the extratropical cyclone.

I wish here to acknowledge my deep indebtedness to Messrs. G. E. Dunn, assistant to the forecasters, and A. J. Haidle and Welby R. Stevens of the Forecast Division of the United States Weather Bureau, for kindly selecting for me the weather maps used in this article.

[1] Jeffreys, Quart. J. Roy. Meteorol. Soc., 52; 85, 1926.

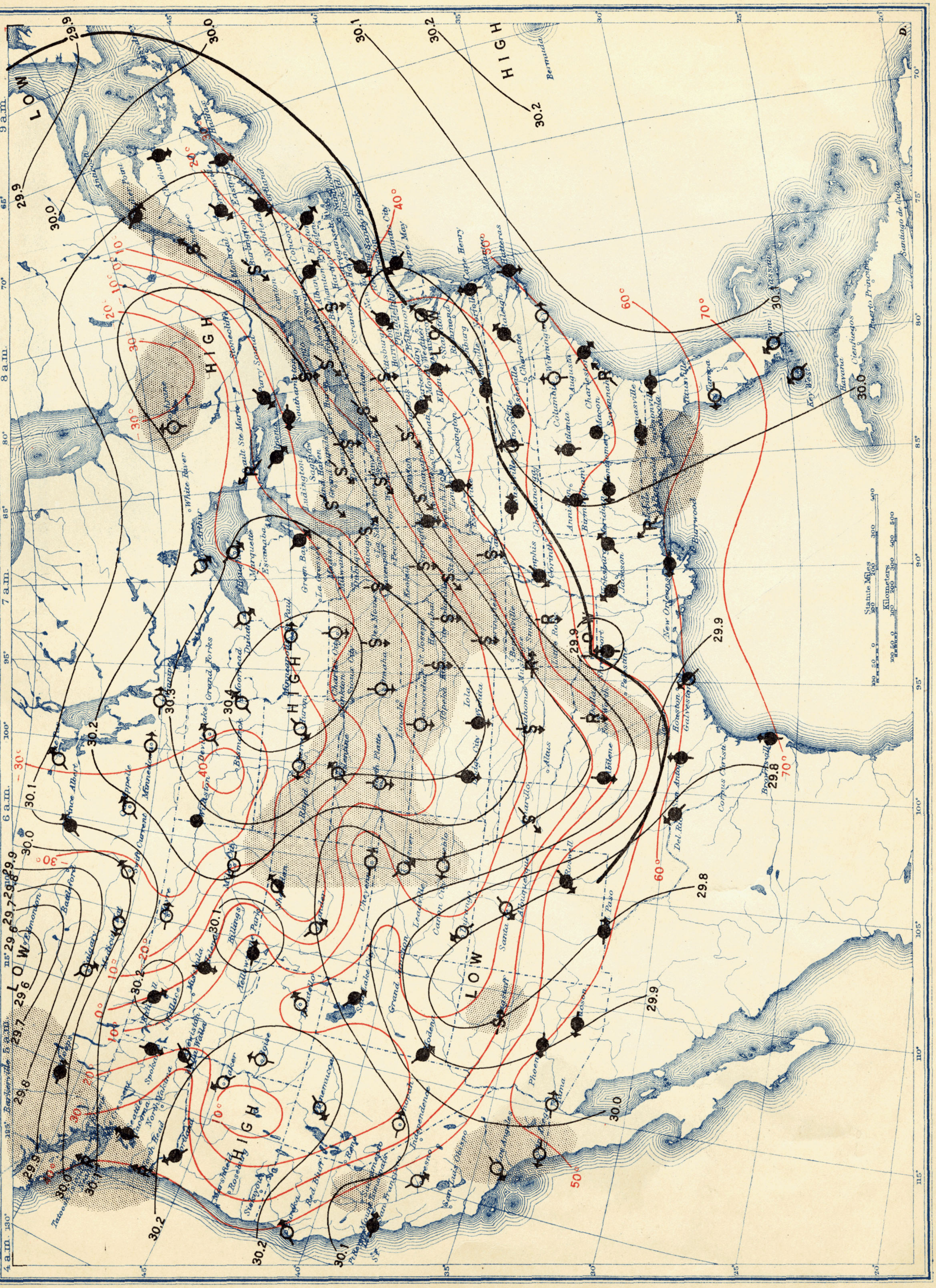


Chart A.—February 19, 1929, 8 a. m.

Chart B.—February 19, 1929, 8 p. m.

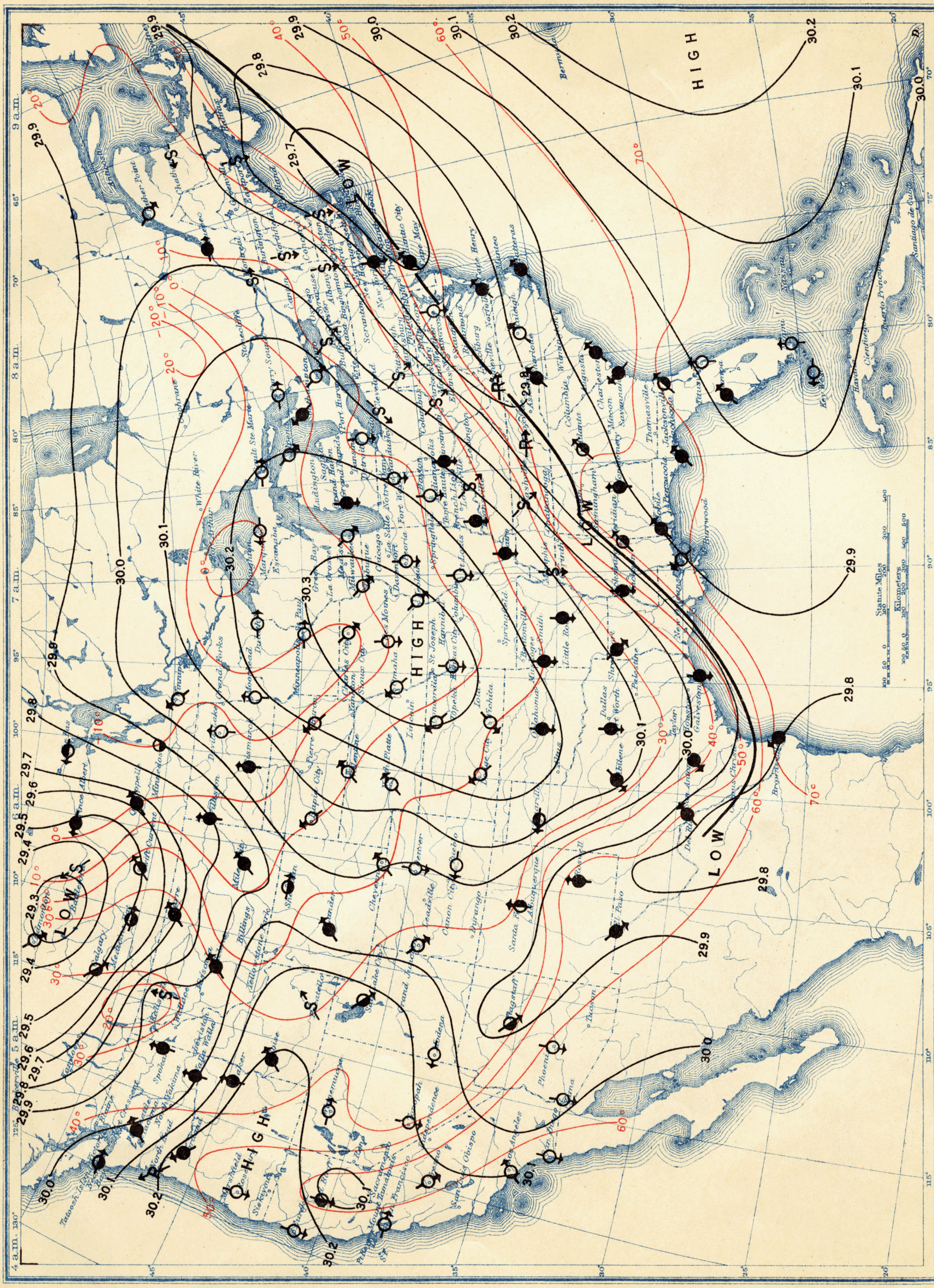
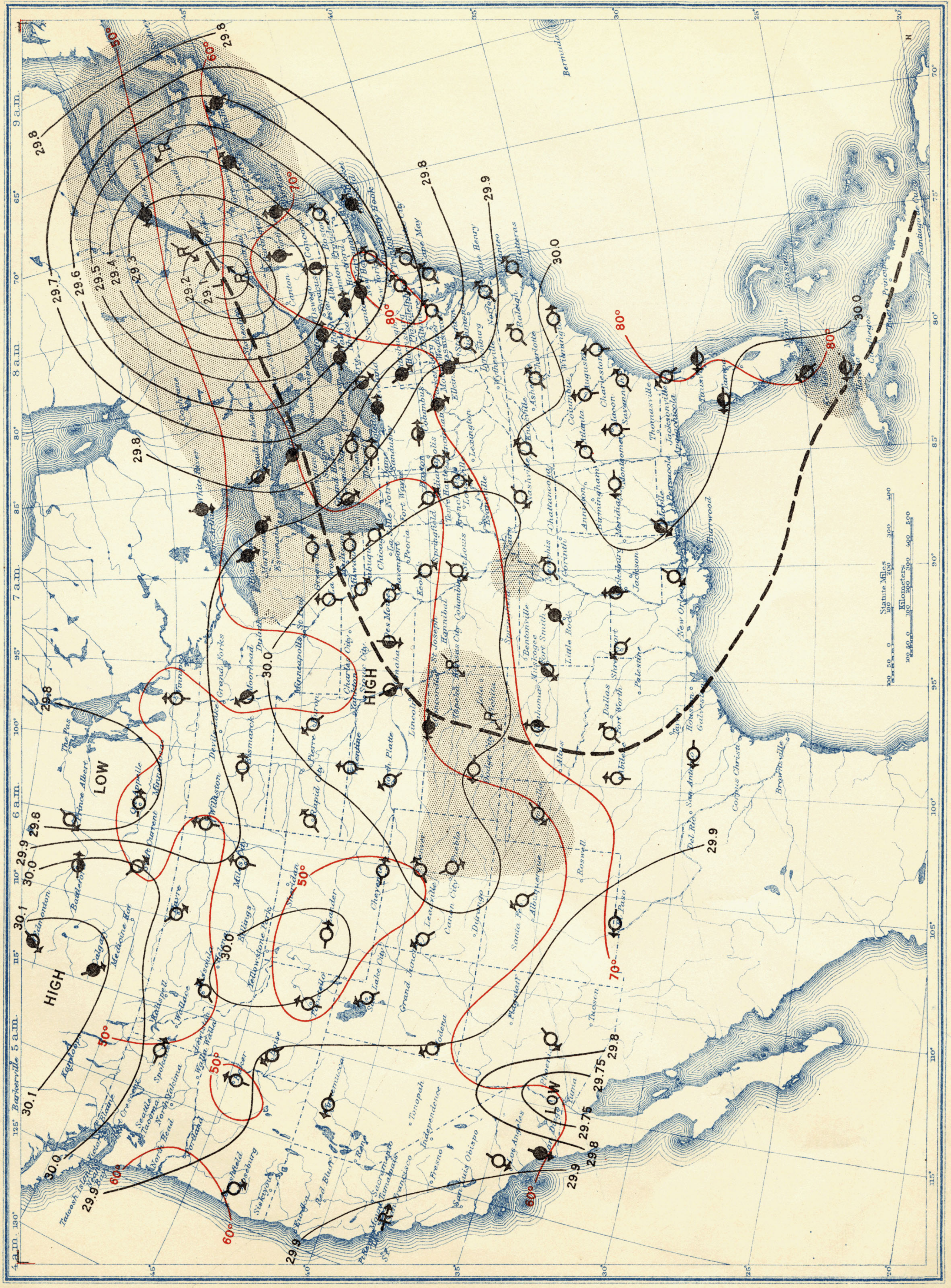


Chart C.—September 12, 1900, 8 a. m.



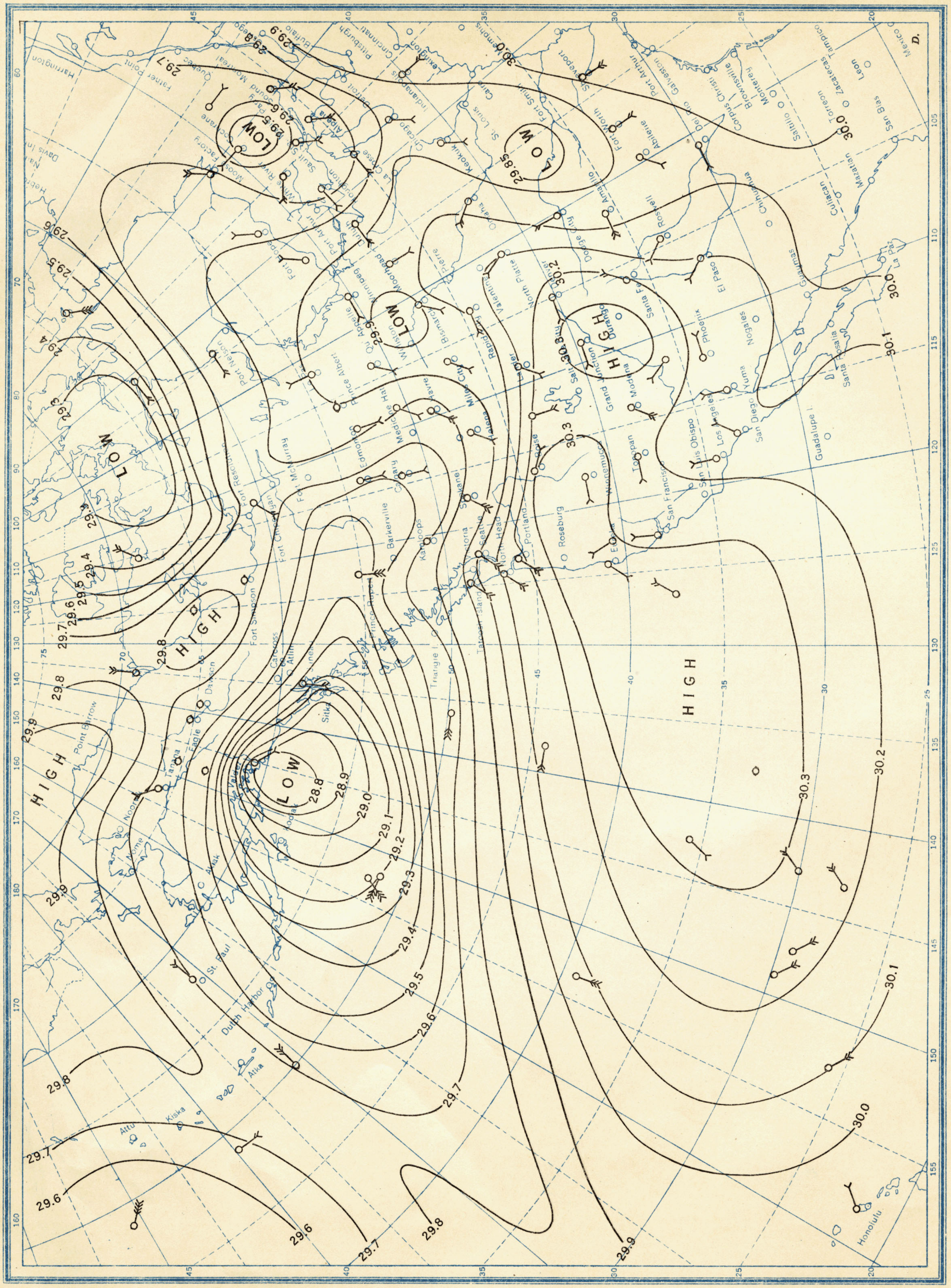


Chart D.—January 4, 1933, 8 a. m.

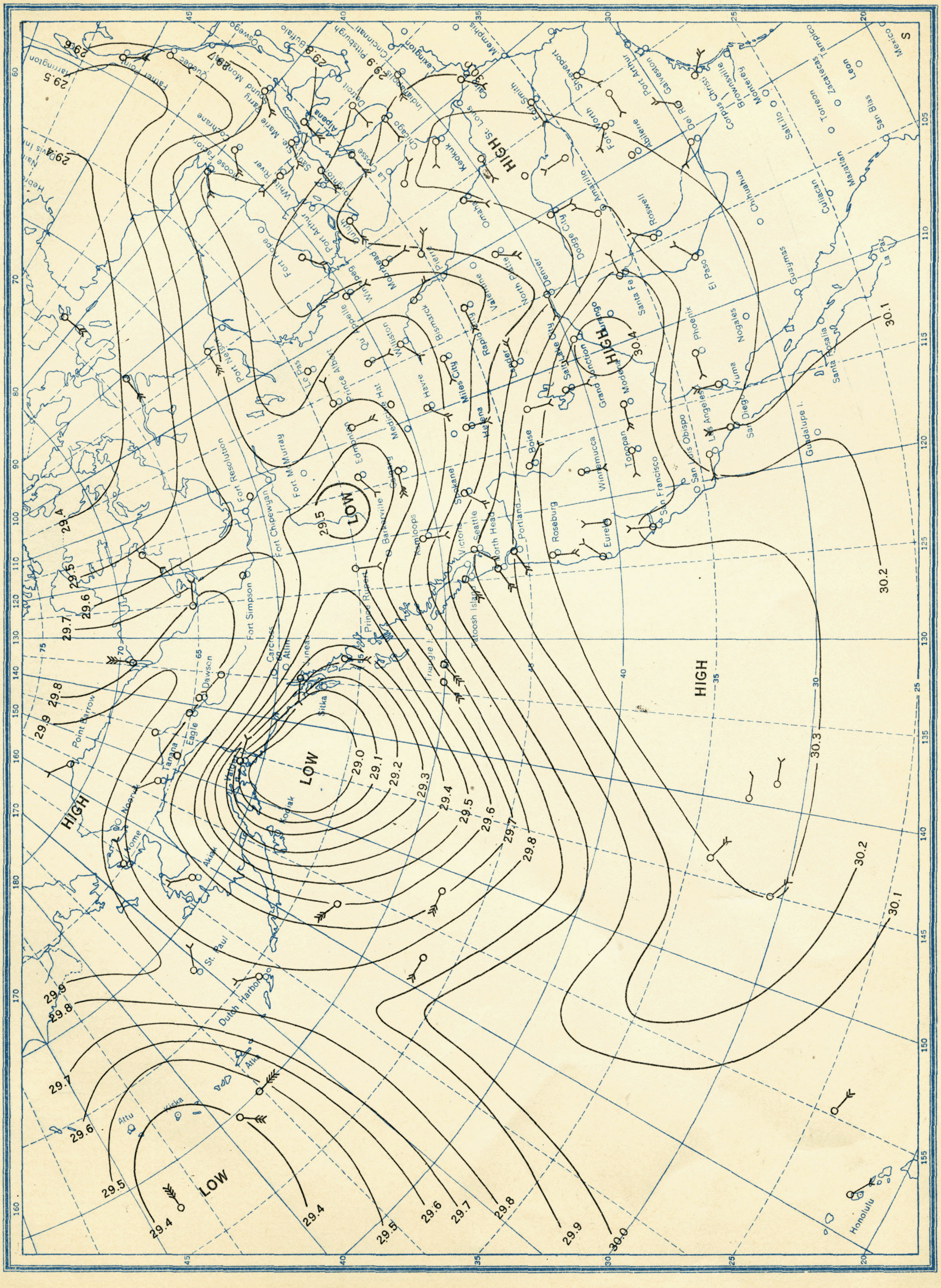


Chart E.—January 4, 1933, 8 p. m.

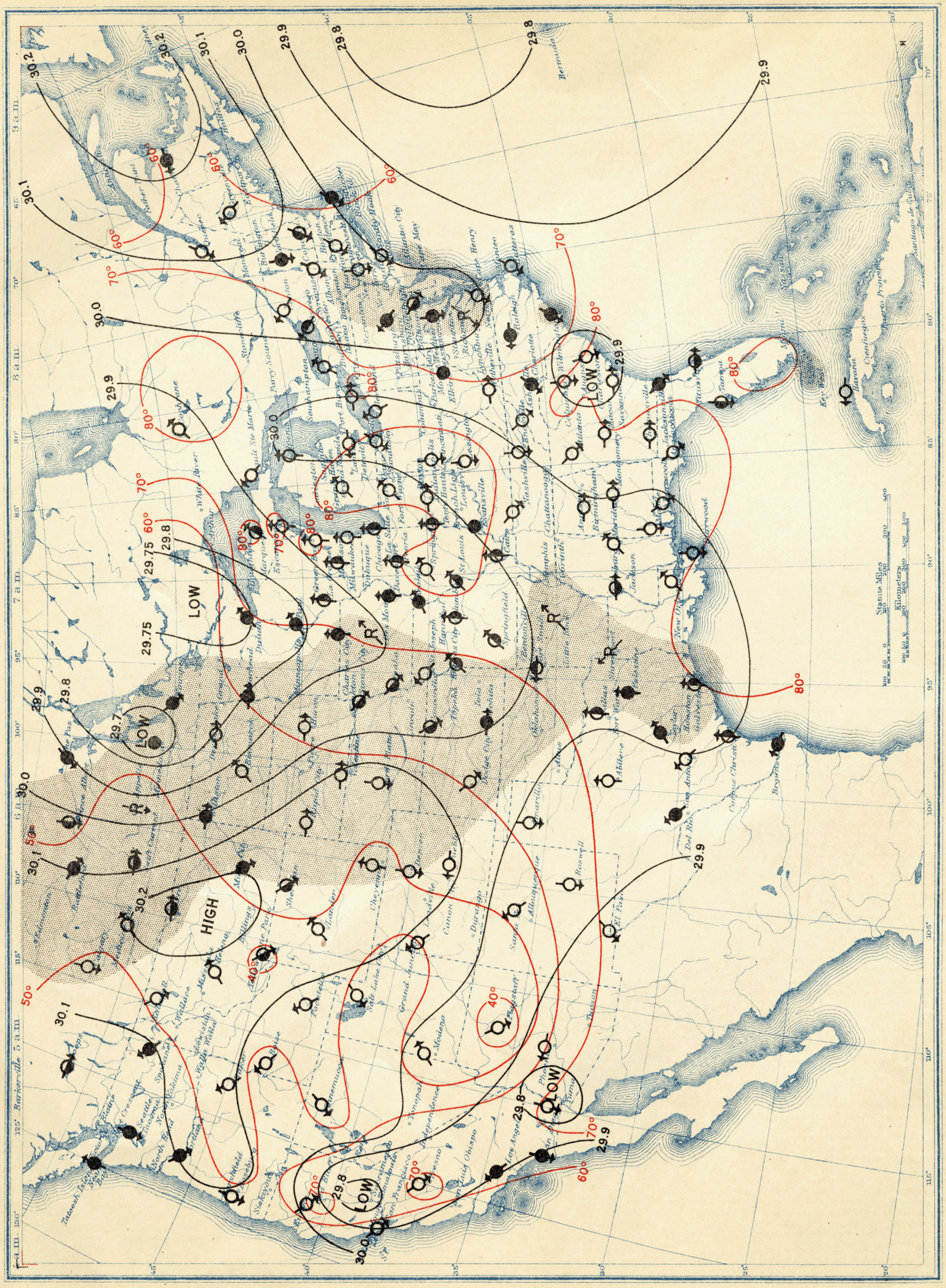


Chart F.—July 1, 1927, 8 a. m.

Chart G.—July 2, 1927, 8 a. m.

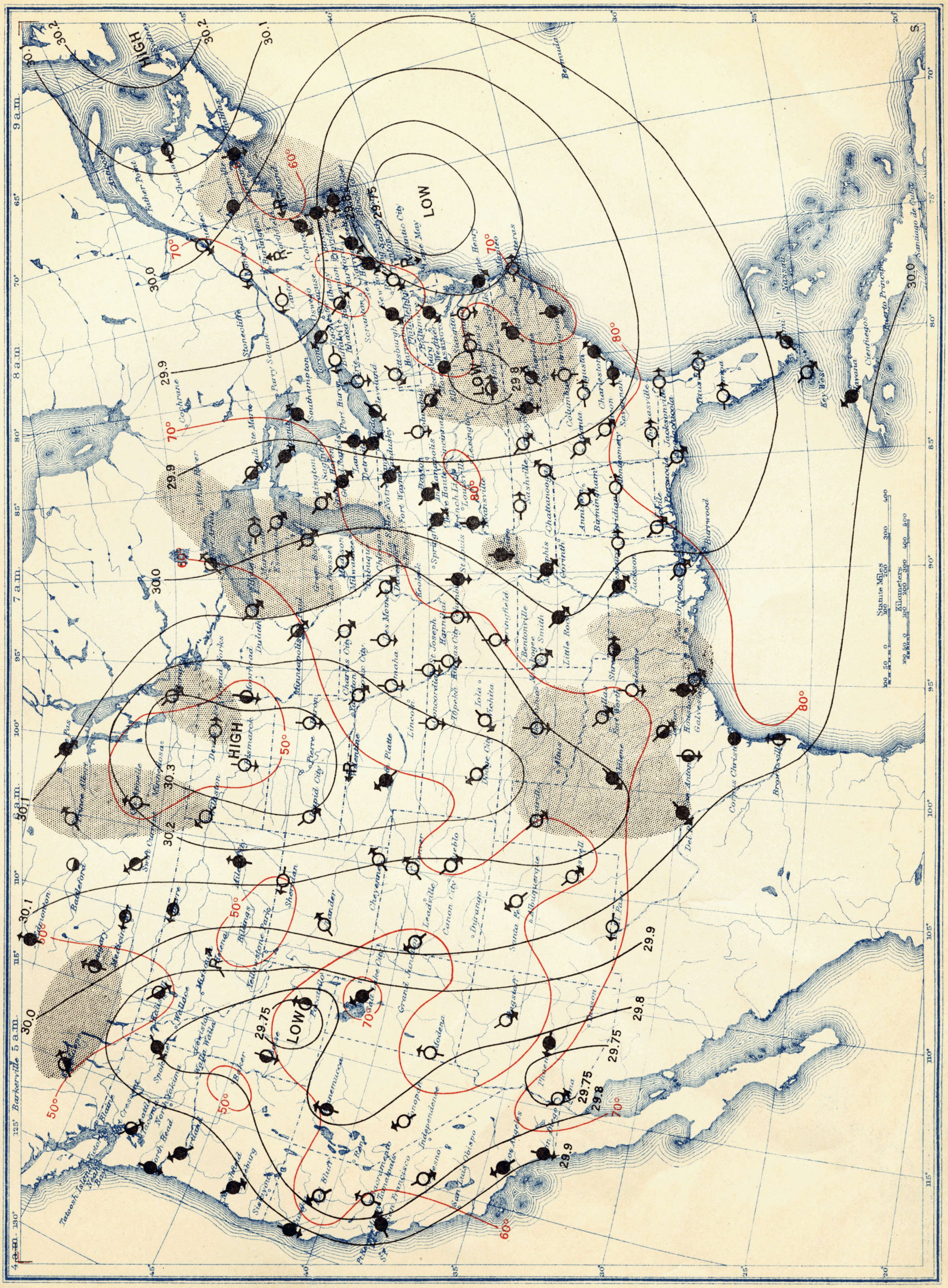
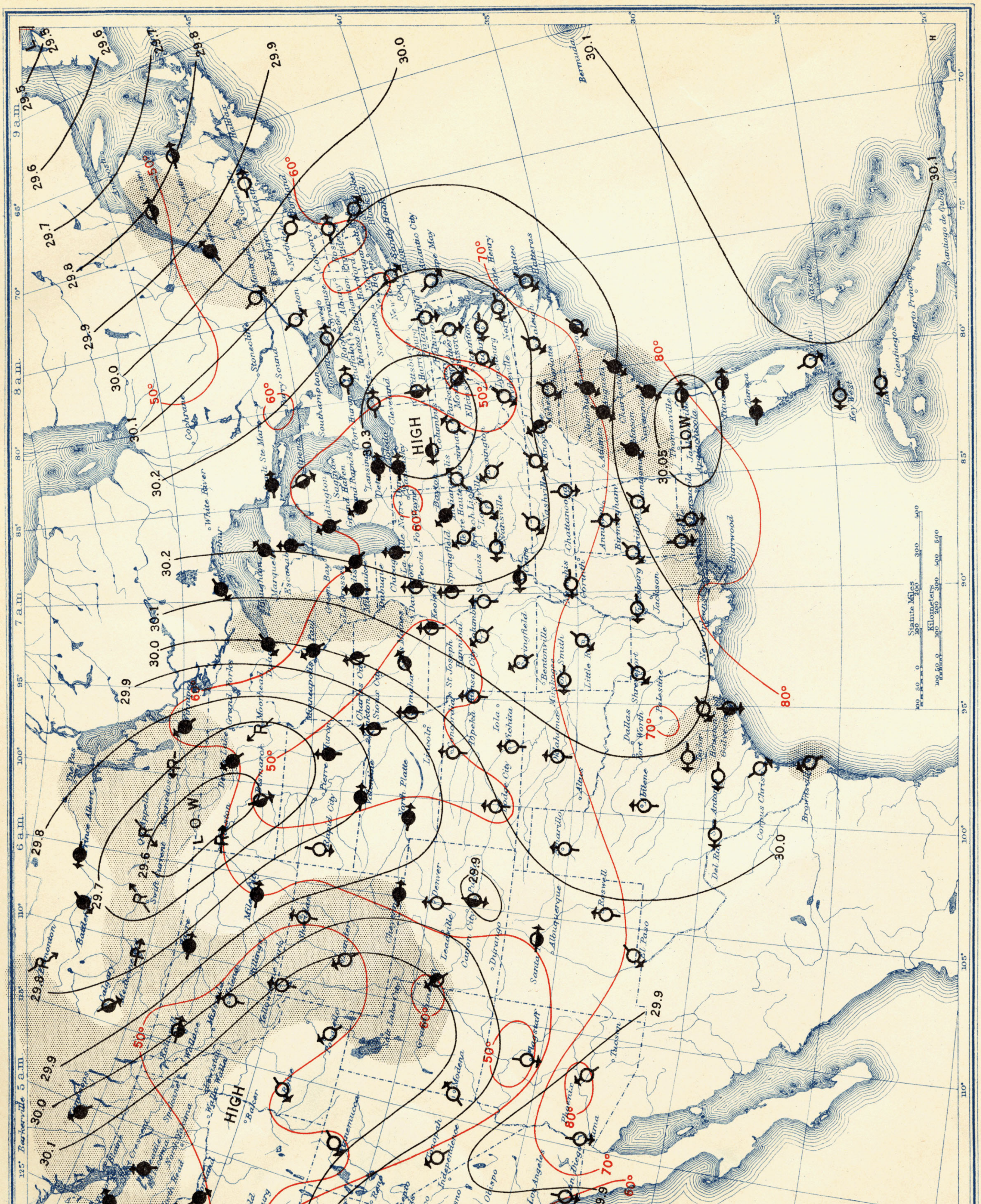


Chart H.—July 5, 1927, 8 a. m.



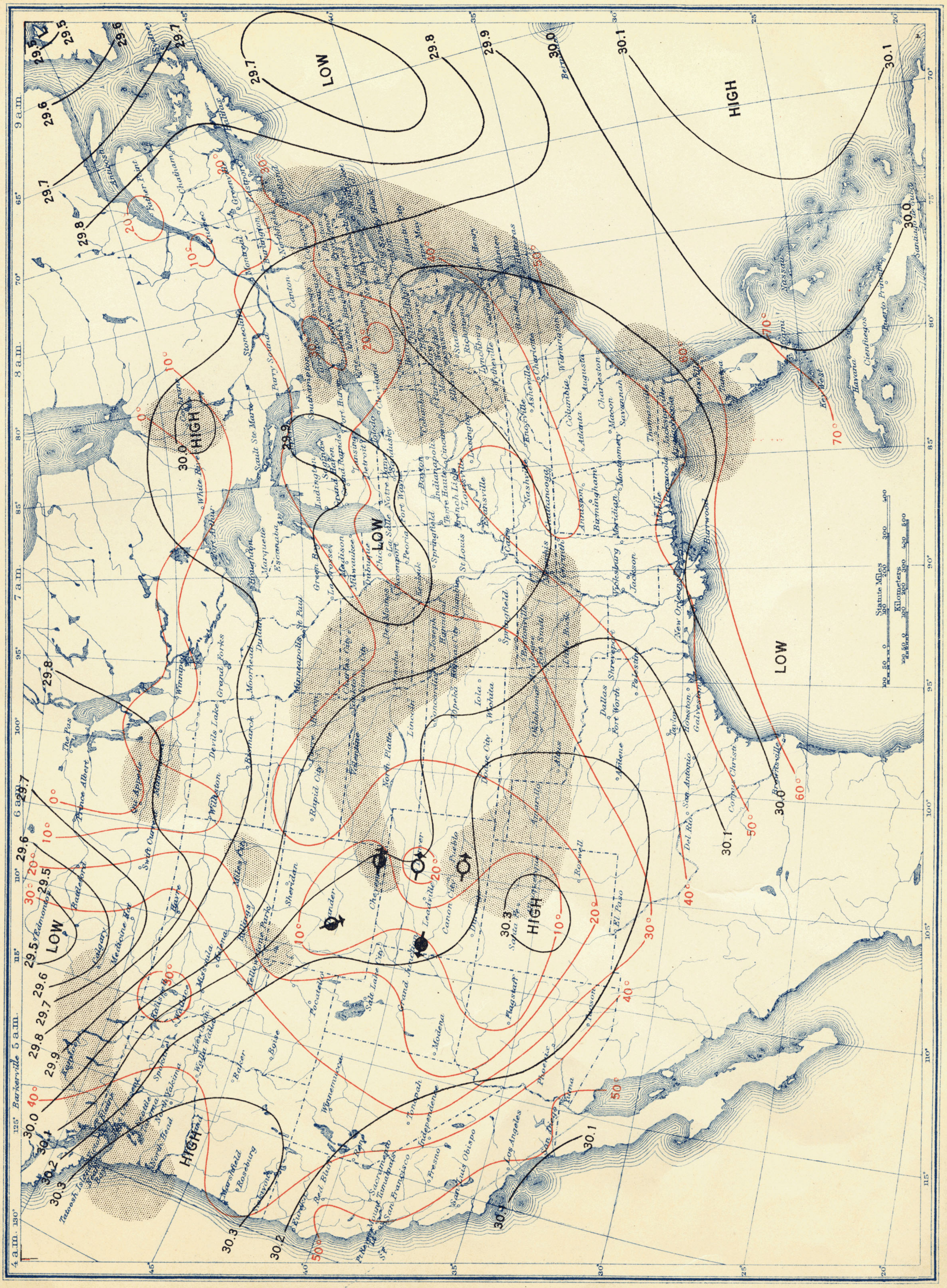


Chart I.—March 1 1929, 8 a. m.

Chart J.—March 1, 1929, 8 p. m.

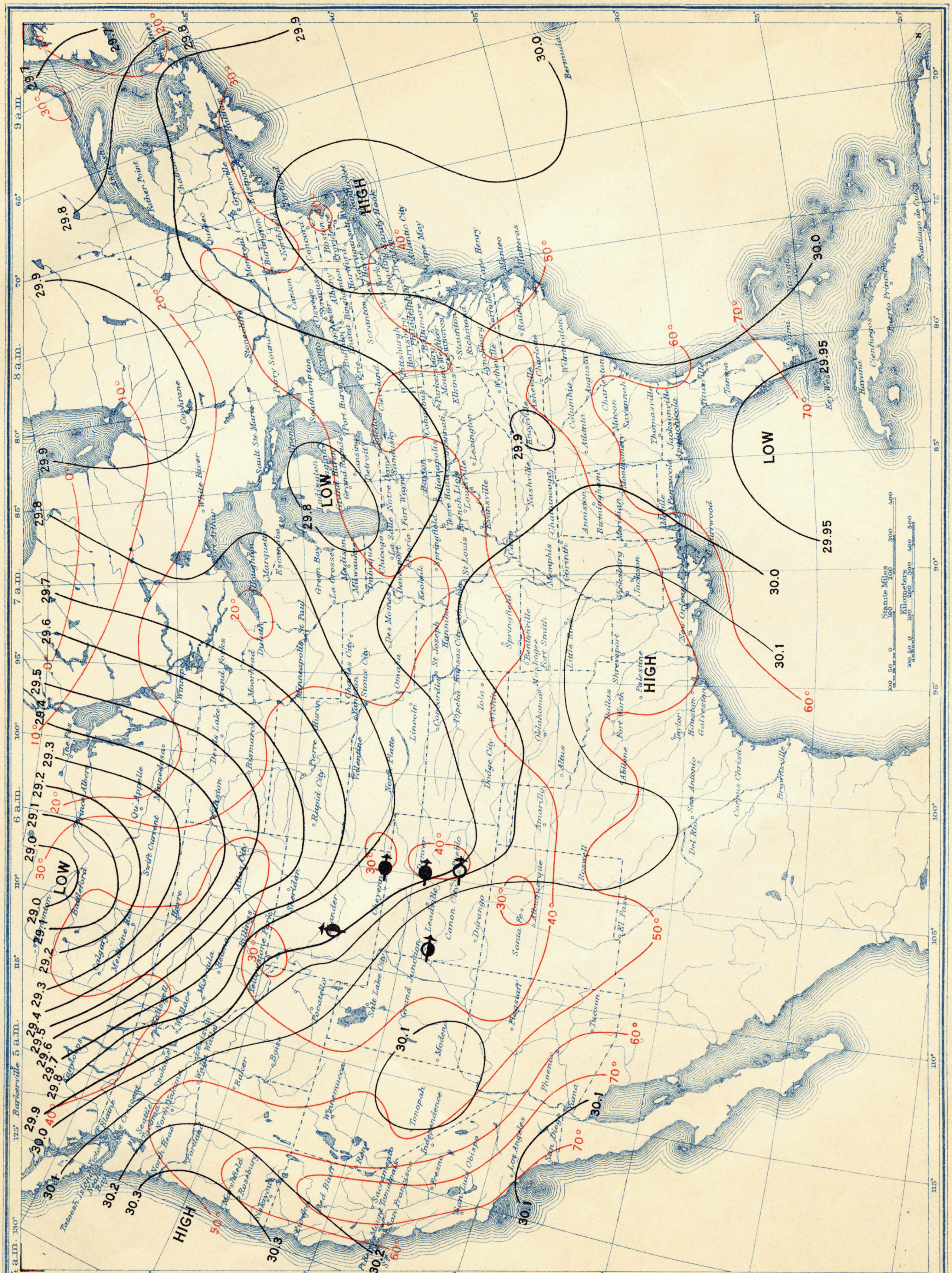
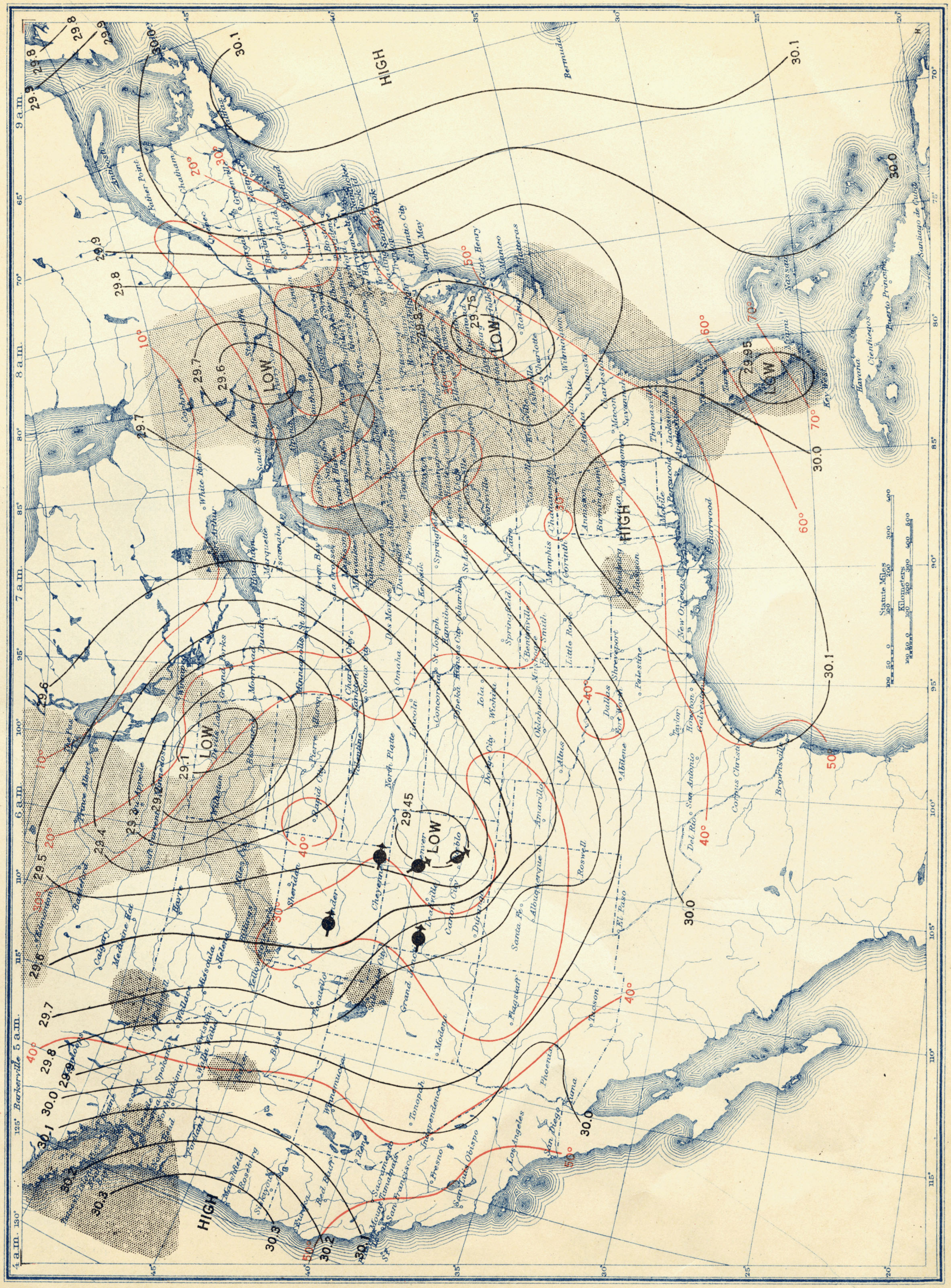


Chart K.—March 2, 1929, 8 a. m.



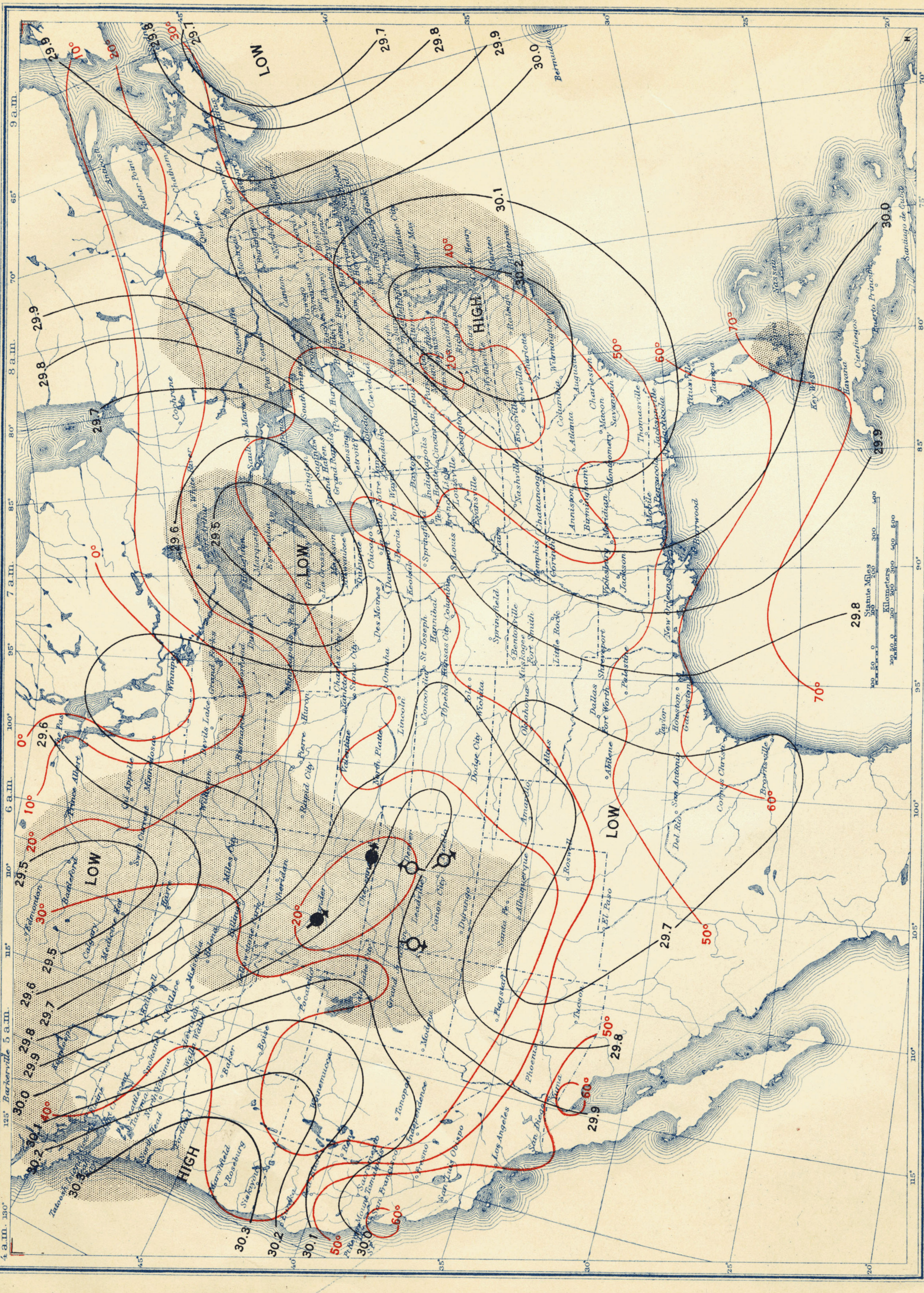


Chart L.—March 3, 1929, 8 a. m.